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# The sum of spread equivalents: a pesticide risk index used in environmental policy in Flanders, Belgium

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**Abstract**

In the framework of a pesticide reduction programme in Flanders, Belgium, an environmental policy plan was adopted in 1995 stipulating a 50% reduction of pesticide use expressed as spread equivalents ($\sum$Seq) in 2005 compared with 1990. The sum of spread equivalents is a single-impact risk indicator. It does not describe an absolute risk but provides a risk trend over the years. The evaluation of pesticide use is reported annually in the Report on the Environment and Nature (MIRA) within the Driving Forces, Pressure, State, Impact and Response analysis framework. A total reduction of 47% of the total $\sum$Seq was accomplished in 2002. Following the withdrawal of hazardous pesticides within the Council Directive 91/414/EEC a further reduction can be expected in the near future.

A comparison was made with four other pesticide risk indices. It can be concluded that the results of all five indices are quite similar and that the use of the $\sum$Seq index as a policy tool in Flanders can be justified.


*Keywords:* Pesticide; Use; Environment; Indicator; Risk

## 1. Introduction

Pesticides are chemical or natural substances used to control all kinds of pests in plants, animals and materials. Pesticides are a necessary tool to provide high crop yields ensuring enough food supply for mankind and high quality of food products. The annual use in the last decade in Belgium is about 10 000 tonnes of plant protection products (PPPs) for agricultural and non-agricultural use (public services, gardens, hard surfaces, non-professional use, etc.) and about 6000 tonnes for the biocides (1994–1996).

Although their use is inevitable for the moment, they can give rise to a range of side effects such as toxicity for the applicator, contamination of the water cycle, toxicity for honey bees, birds, useful arthropods, etc. Because of their eco-toxicity, possible bio-accumulating properties and endocrine disrupting effects, pesticides are of special interest for the environment and the public health. This has led to the decision by the Flemish authorities to propose a 50% reduction of pesticide use (expressed as spread equivalents) between 1990 and 2005.

A large number of policy powers in Belgium, including environmental policy planning, have been transferred from the national (federal) state (i.e. Belgium) to the Regions (i.e. Flanders, Wallonia, and Brussels). Although pesticide authorization is a national matter, pesticide reduction policies presented here are only relevant for Flanders. It only applies to the Flanders Region, but provides some figures on the national level.

In 1995, the decree on general provisions concerning environmental policy (action 32 of Environmental

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Policy and Nature Development Plan (MINA) II) was the onset for integral environmental planning in Flanders (Belgisch Staatsblad, 1997). It stipulates the objectives and principles of the Flemish environmental policy and provides the legal basis for a long-term policy on how to deal with the environment in a sustainable way. The state of the environment is presented annually in the Report on the Environment and Nature (MIRA) according to the DPSI-R chain (Driving Forces, Pressure, State, Impact and Response), a widespread analysis framework within international environmental reporting (Smeets and Weterings, 1999; Van Steertegem, 2003). It is within this framework that pesticide use and possible side effects are reported on an annual basis in Flanders.

Several types of risk indicators can be used in order to describe the pressure on the environment. Use indicators such as the annual pesticide use (kg) and application dose ($kg\,ha^{-1}$) are pesticide indices solely based on pesticide use, crop acreage and applied dose. Pesticide properties such as persistence and toxicity data are not included in these indicators. Single-impact risk indicators consider one specific aspect of the possible impact of pesticide use on the environment taking into account pesticide properties. Whereas the aquatic eco-system is considered to be the most sensitive ecosystem in the environment, these indicators in general describe the impact on this compartment using the toxicity data of the three trophic levels (fish, crustaceae and algae).

Multi-impact risk indicators such as the POCER indicator (Vercruysse and Steurbaut, 2002) and the Environmental Yardstick for Pesticides (EYP) (Reus and Leendertse, 2000) calculate the impact on several compartments. The EYP describes, in addition to the aquatic risk, the possible impact on soil organisms and risk for leaching to groundwater, whereas the POCER even considers 10 aspects: human exposure (pesticide operator, worker and bystander) and environmental risk (persistence, leaching, aquatic and soil organisms, birds, bees and beneficial arthropods).

An evolving knowledge of the physico-chemical and eco-toxicological properties (the so-called pesticide end points) within the framework of the Council Directive 91/414/EEC provides a better understanding of the processes involved in the environmental distribution and degradation of pesticides and a better insight of the possible impact on non-target organisms can be obtained. This can result in improved risk indicators and environmental models. However, given the complexity and site specificity of natural ecosystems, such improved indicators and models will narrow the applicability and predictions and a more site-specific approach is necessary. Use of these indicators will result in better estimations of possible environmental contamination and side effects, but the applicability on a more regional scale will require an even larger dataset of all the influencing factors (pesticide properties, application method, environmental conditions, etc.), whereas policy makers do need simple tools or indicators to evaluate risk trends. This can be seen in Flanders, Belgium ($\sum$Seq) (Steurbaut et al., 2003), the Netherlands (annual pesticide use) (Ekkes et al., 2001) and Denmark (frequency of application) (OECD, 2002) who have adopted such easy-to-use risk indicators in their environmental policy plan.

## 2. Materials and methods

### 2.1. Pesticide use

Sales data of PPPs are provided by the Belgian Federal Public Services for Health, Food Chain Safety and Environment expressed as mass of the active ingredient. Data are available from 1979 until 2002. Sales data are reported on an annual basis except in the period 1979–1991 when data were provided every 3 years. For years in which no sales data are available, an estimate is made by linear interpolation. The sales data of individual compounds are confidential on grounds of competition, so pesticide consumption data can only be presented as a group of pesticides (insecticides, herbicides, fungicides, etc.) or as the total amount used in various crops. The export of pesticides is accounted for in the sales data. The import and keeping in stock of pesticides means the actual use can differ from the sales data. However, this is thought to account only for a small percentage. Therefore, sales data provide a good estimate for pesticide use.

Van Lierde and Van den Bossche (2002) reported pesticide use data in arable farming and horticulture in Flanders, Belgium. A total of 1853 farms (from a total of 104,018 farms) were investigated and the results were extrapolated to the scale of Flanders. The distribution of pesticide use in 13 crop groups (beets, potatoes, cereals, maize, industrial crops, grass land, forage plants, fruits, vegetables, ornamental plants, greenhouse flowers, greenhouse fruits and greenhouse vegetables) and non-agricultural use could be made for each individual compound. In this manuscript horticulture represents fruits, vegetables and ornamental crops in field and in greenhouses. The cultivation of beets, cereals, maize, potatoes, industrial crops, grass land and forage crops is referred to as arable farming.

### 2.2. Evaluation of pesticide use using the $\sum$seq risk indicator

It has become widely acknowledged that pesticide weight and volume are not adequate proxies for assessing the risk of non-target impact of pesticides. Different chemicals can have quite different properties

and potencies, resulting in a different environmental fate and transport and possible effects on non-target organisms. It is from this point of view that pesticide risk cannot be assessed adequately solely based on the amounts of pesticides used or the number of applications. Therefore, risk-weighted indicators are a better measure for possible environmental impact (Levitan, 2000). It is from this point of view that the $\sum$Seq index was adopted in the environmental policy plan in Flanders in 1995.

The $\sum$Seq index is calculated using the following formulae:

$$\sum_{\text{all active ingredients}} \mathrm{Seq} = \frac{DT_{50}E}{MPC},$$

$$MPC = \frac{NOEC_{lowest}}{Safety\ Factor},$$

with $E$ the total usage of active ingredient (kg year$^{-1}$), $DT_{50}$ the soil half-life (days), and $MPC$ the maximum permissible concentration (mg L$^{-1}$).

Using these equations pesticide use is weighted for persistence and the eco-toxicity in the environment for each compound. The total Seq ($\sum$Seq) is calculated by summation of the spread equivalents of all active ingredients. Pesticide use data are derived from sales data as described earlier. Datasets for the soil half-life and eco-toxicological values of the active ingredients are obtained from several sources (in order of importance):

1. Final technical review reports within the framework of the Council Directive 91/414/EEC on placing PPPs on the market.
2. Drafts of the review reports to be submitted within the framework of the Council Directive 91/414/EEC obtained from Phytofar, the Belgian Association of PPPs Industry, in confidence.
3. Pesticides database of the Board for the Authorization of Pesticides in The Netherlands (CTB).
4. Linders et al. (1994).
5. The Pesticide Manual 12th edition (Tomlin, 2000).

The maximum permissible concentrations in water are derived from the procedure for the setting of chemical quality standards as described in Annex V of the EC Water Framework Directive 2000/60/EC. Depending on the availability of acute and chronic toxicity data for the three trophic levels (fish, daphnia or representative for saline waters and algae), appropriate safety factors are used in order to obtain the MPC value from the eco-toxicological data. When available, toxicity data for daphnia (representative for crustaceae) and rainbow trout (representative for fish) were used in our calculations. For the different algae species the highest toxicity was taken into account. From these three trophic levels the highest chronic toxicity (NOEC with lowest value) was derived and the appropriate safety factor was used to calculate the MPC. When no chronic data are available, the highest acute toxicity was taken into account.

The $\sum$Seq only describes the possible impact on water life and does not account for possible bio-accumulating properties, synergistic and endocrine disrupting effects. The $\sum$Seq is not an absolute measure for the actual risk or toxicity for aquatic organisms, but describes a risk trend over the years. Therefore, the evolution of the $\sum$Seq will be presented compared with a 100% value in 1990 (index 1990 = 100).

### 2.3. Comparison with other pesticide risk indicators

As the $\sum$Seq index is stipulated in the environmental policy plan in Flanders, it is useful to compare the index with other pesticide risk indices. This way the choice of the $\sum$Seq index and its usefulness can be questioned and/or be supported. Reus et al. (2002) compared and evaluated eight pesticide environmental risk indicators developed in Europe within the CAPER project (concerted action with regard to pesticide risk indicators). Most of these eight indicators were developed as a decision tool for farmers to select pesticides with the least environmental impact, whereas some others have been developed as a tool for policy makers. So both scale and purpose of these indicators can be quite different. From these eight risk indicators, two were selected to make a comparison with the $\sum$Seq index: the EYP used in the Netherlands as a decision tool on farm level (Reus and Leendertse, 2000) and SyPEP developed in Belgium for policy makers (Beernaerts and Pussemier, 1997; Pussemier, 1999; Reus et al., 2002). Two additional risk indices were selected: the proposed REXTOX index from the OECD Working Group on Pesticides' Aquatic Risk Indicators (OECD, 2000) and the Load Index developed by Danish scientists (OECD, 2002). Formulae of these indices are shown in Table 1.

Although the $\sum$Seq and Load Index account for the toxicity for water organisms, they do not consider the different emission routes and load to the environment. Therefore, these indices are a measure for the evolution of pesticide usage expressed as "toxic equivalents".

SyPEP, EYP and REXTOX on the other hand are indices which estimate pesticide losses to nearby surface waters. The predicted environmental concentration PEC is calculated and compared with eco-toxicity data for water organisms. For all indices the derived MPCs values rather than L(E)C or NOEC data were used in our calculations. For the EYP risk indicator only the risk for water life was calculated. For these three indices application type and crop type were taken into account. For greenhouse cultivation the amount of spraydrift was assumed to be zero. In addition, the spraydrift for all pesticides which are applied not as a spray mixture (i.e.

Table 1
Formulae for the calculation of the selected pesticide indices

| Index | Formulae | Description of the parameters |
|---|---|---|
| LI | $LI = \sum_{all\ active\ ingredients} \frac{E_{each\ active\ ingrendient}}{TOX \times Agra_{year}}$ | $E$: annual sales date of each active ingredient |
| | | $TOX$: toxicity for water organisms |
| | | $Agra$: crop acreage (ha) |
| EYP | $PEC_{ditch} = \frac{AR \times \%Spraydrif}{Depth}$ | $AR$: application rate (kg ha$^{-1}$) |
| | $EYP = \sum_{all\ active\ ingredients} \frac{PEC_{ditch}}{TOX_{year}}$ | $Spraydrift$ (%): amount of spraydrift according to Ganzelmeier (1997) |
| | | $Depth$: depth of the ditch (default value = 0.3 m) |
| | | $TOX$: toxicity for water organisms |
| REXTOX | $REXTOX = \sum_{all\ active\ ingredients} \frac{E}{TOX} \times (L\%_{spraydrift} + L\%_{runoff})$ | $E$: total pesticide use based on annual sales data of each active ingredient |
| | | $TOX$: toxicity for water organisms |
| | | $L\%drift$: amount of spraydrift according to Ganzelmeier (1997) |
| | | $L\%\ runoff$: amount of indirect load caused by run-off (OECD, 2000) |
| SyPEP | $APESUW = f(\%Spraydrift, \%Directlosses, \%Runoff, \%drainage)$ | $APESUW$: amount potentially expotable to surface waters. Emission factors (%) for direct and indirect losses are given below: |
| | | Direct losses[a] 0.25 |
| | | Spraydrift[a] 0.051 for fruit; 0.004 for others |
| | | Run-off[b] 0.4 |
| | | Drainage[b] 0.01 if GUS < 3[c] |
| | | 0.1 if 3 < GUS < 4 |
| | | 1 if 4 < GUS < 4.5 |
| | | 10 if GUS > 4.5 |
| | $PCOW = \frac{APESUW}{rain(mm) \times SPR}$ | $PCOW$: predicted concentration in outflowing water |
| | | $Rain$: 780 mm year$^{-1}$ in Belgium |
| | | $SPR$: standard percentage run-off = 0.33 |
| | $PECsw = PCOW \times (1 - BFI)$ | $BFI$: base flow index = 0.5 |
| | | $PEC_{sw}$: predicted environmental concentration in surface waters |
| | $SyPEP = \sum_{all\ active\ ingredients} \frac{PECsw}{TOX}$ | $TOX$: toxicity for water organisms |

[a]Total amount used.
[b]Total amount emitted to soil.
[c]Groundwater ubiquity score: $GUS = \log DT_{50}(4\text{-}\log K_{oc})$.

seed treatment, granules and dipping) were also set to zero.

## 3. Results and discussion

### 3.1. Trends of pesticide use data in Flanders

Fig. 1 describes the evolution of pesticide use data based on sales data between 1990 and 2002. Annual use dropped from 6.3 and 9.8 million kg in 1990 to 5.5 and 9.2 million kg in 2002 for Flanders and Belgium, respectively. Annual fluctuations, such as the increase in 1992, are mainly caused by a different infection pressure reflecting variable environmental conditions. The average use between 1990 and 2002 in arable farming and horticulture is estimated at 70% of the total annual pesticide consumption. Pesticide use for non-agricultural and non-professional purposes accounts for 30%. No important changes are observed within this period.

Separated into the various pesticide categories, herbicides account for 54.8% of the total amount used in Flanders considering both the agricultural and non-agricultural consumption (Fig. 2). The level of herbicide use was 2.8 million kg in 1990 and despite of annual fluctuations remained almost unchanged. The use of fungicides (29.9%) and insecticides (11.2%) is lower. For both fungicides and insecticides a reduction of 20.7% and 49.1%, respectively, in 2002 compared with

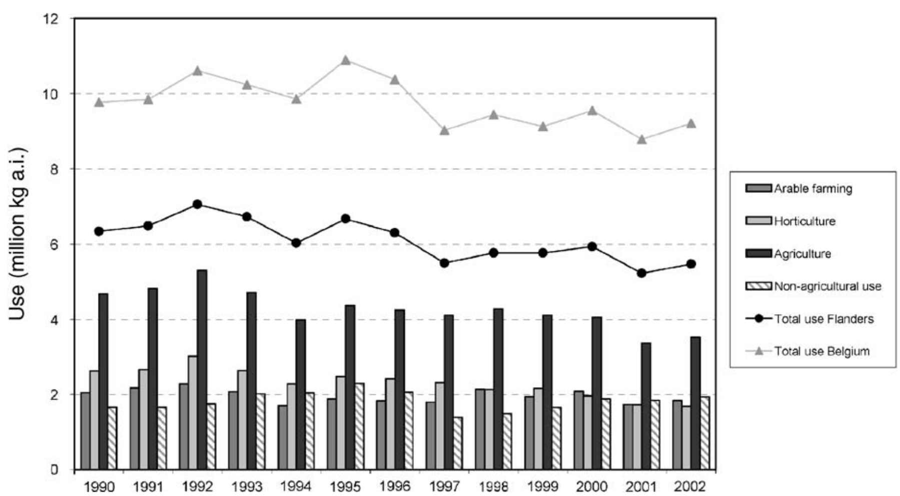


Fig. 1. Sales of pesticides in Flanders ($10^6$ kg a.i.) between 1990 and 2002.

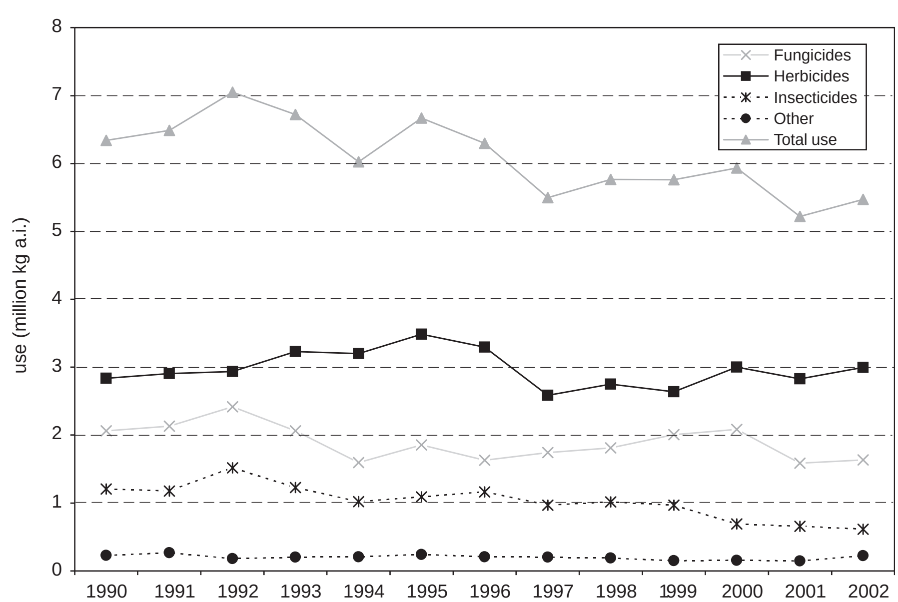


Fig. 2. Sales of pesticides in Flanders ($10^6$ kg a.i.) separated into various pesticide categories between 1990 and 2002.

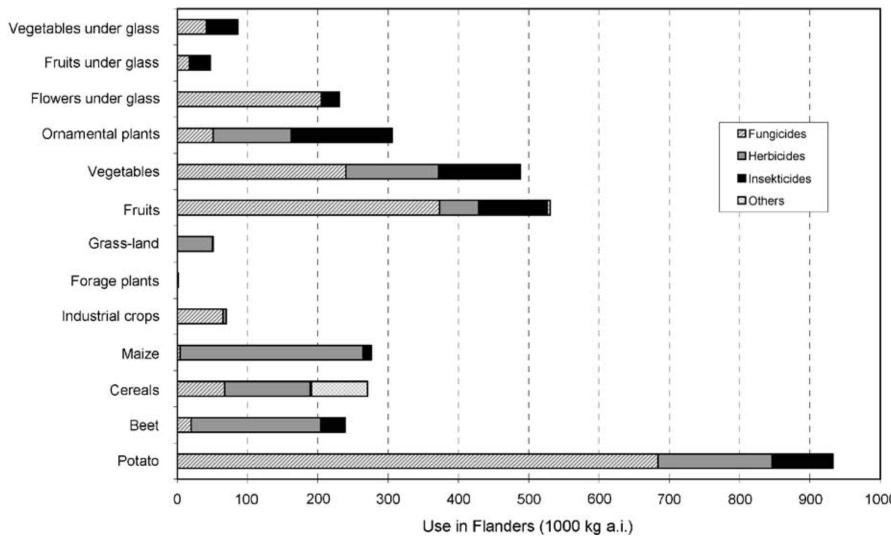


Fig. 3. Sales of pesticides (1000 kg a.i.) per crop differentiated for the pesticide categories in Flanders in 2002.

1990 was accomplished. Other types of pesticides such as disinfectants, rodenticides and growth regulators account for only 4.1%.

However, when only arable farming and horticulture are considered, thus excluding non-agricultural use, fungicides become the most important group (50.1%). Herbicides and insecticides account for 30.7% and 16.7%, respectively. Herbicides are by far the most important type (92.7%) in the non-agricultural sector. Insecticides account for only 4.5%, whereas the use of fungicides is less than 1%.

Fig. 3 summarizes pesticide use (kg year$^{-1}$) by crop type in Flanders in 2002 as a whole and differentiated for the pesticide categories. Only arable farming and horticulture are considered. Potato cultivation is responsible for the highest consumption (26.4% of a total use of 3.53 million kg in the agricultural sector), mainly because of the large amounts of fungicides used. Further analysis showed the following distribution by crop: fruits (15.0%), vegetables (13.8%), ornamental crops (8.7%), maize (7.8%), cereals (7.7%), beets (6.8%), greenhouse flowers (6.5%), greenhouse vegetables (2.4%), industrial crops (2.0%) and greenhouse fruits (1.3%). Minor uses can be found on grass land (1.4%) and forage plants (<0.1%).

Large amounts of pesticide consumption per ha can be found mainly in horticulture. The cultivation of ornamental plants such as roses, azaleas, lilies, etc. involves an intensive use of pesticides (61.1 kg ha$^{-1}$ year$^{-1}$), whereas the use of vegetables and fruits was 19.9 and 32.9 kg ha$^{-1}$ year$^{-1}$, respectively. Similar results were found in the Netherlands in 1998 by De Jong et al. (2001). In arable farming, the highest amounts per ha are applied on potatoes (23.3 kg ha$^{-1}$ year$^{-1}$), from the intensive use of fungicides.

Fig. 4 describes the evolution of the amount of pesticide used (kg ha$^{-1}$ year$^{-1}$) in some selected crops. Due to changeable crop acreages, this method is preferred rather than calculating the evolution of the amounts used per crop (kg year$^{-1}$).

Fig. 4 shows a decrease of the annual use of pesticides per ha since 1990 for all selected crops. High reductions in 2002 compared with 1990 are observed in horticulture: vegetables (−30.9%), fruits (−51.1%) and ornamental crops (−43.6%). In arable farming similar results are observed: maize (−39.0%), cereals (−33.5%), beets (−15.5%) and potatoes (−9.7%).

Cultivation of vegetables, fruits and flowers in greenhouses requires high amounts of pesticide consumption: 73.7, 191.7 and 300.9 kg ha$^{-1}$ year$^{-1}$, respectively, in 2002. Whereas several harvests per year can be expected for greenhouse crops, the number of harvests should be accounted for in these figures. Therefore, the figures mentioned above present the total use per year per ha and not necessarily the pesticide consumption required for a single harvest. In comparison with 1990, a high reduction of the pesticide use per ha are also observed in greenhouse cultivation: fruits (−75.8%) and vegetables (−68.6%). The pesticide use for greenhouse flowers increased with 9.3%.

Whereas annual fluctuations in pesticide use are mainly controlled by variable environmental conditions and thus infection pressure, a more structural change is responsible for the ongoing decrease in pesticide use since 1992. Different types of measures or voluntary actions can be responsible for a reduction in total pesticide consumption. Measures in general have an effect on the sector as a whole whereas voluntary actions take place in a more specific segment of the agricultural activities.

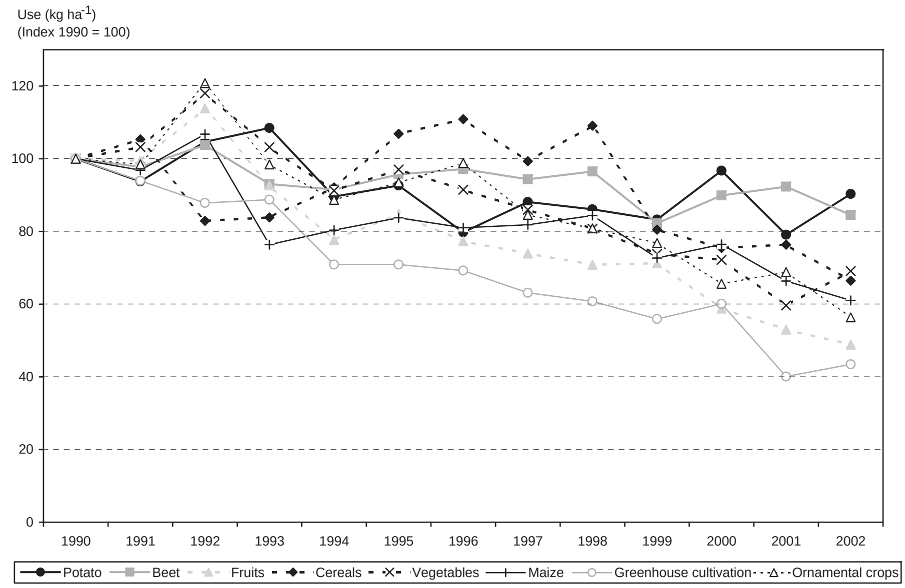


Fig. 4. Trends of pesticide use (kg ha$^{-1}$) in Flanders in selected crops between 1990 and 2002 (index 1990 = 100).

Table 2
Acreages of different crop groups in 1979, 1990 and 2002

| | 1979 | 1990 | 2002 |
|---|---|---|---|
| Potatoes | 28 562 | 36 022 | 39 967 |
| Beets | 54 763 | 53 076 | 40 225 |
| Cereals | 158 114 | 135 272 | 87 225 |
| Maize | 57 061 | 101 412 | 160 354 |
| Industrial crops | 6624 | 6608 | 10 877 |
| Forage plants | 1471 | 6724 | 1082 |
| Grass-land | 298 157 | 261 327 | 235 670 |
| Fruits | 11 029 | 11 907 | 15 942 |
| Vegetables | 14 958 | 22 996 | 27 588 |
| Ornamental crops | 2649 | 3687 | 5006 |
| Greenhouse flowers | 495 | 575 | 768 |
| Greenhouse fruits | 289 | 156 | 244 |
| Greenhouse vegetables | 983 | 1064 | 1169 |
| Total Acreage | 635 155 | 640 794 | 626 117 |

Data obtained from the National Institute for Statistics Belgium (NIS).

From the beginning of the 1990s a substitution of "old generation" pesticides with "new generation" pesticides, which are in general applied at a much lower dose (g ha$^{-1}$ instead of kg ha$^{-1}$) can be observed, e.g. in the cultivation of potatoes the substitution of the fungicide maneb (1.6–3.0 kg ha$^{-1}$) with fluazinam (0.15 kg ha$^{-1}$). Such substitutions should result in a reduction of the total pesticide consumption if the same number of applications can be assumed. Levitan (2000) reported that despite many newer pesticides that are applied at lower volume per unit area, pesticide usage in the US doubled over the last 35 years. In Belgium, pesticide use increased from 6.8 million kg in 1979 to 10.6 million in 1992. From 1992 a continuous decrease was observed except for 1995. From Table 2 it can be seen that the total agricultural acreage remained nearly unchanged. However, significant changes can be observed with respect to the type of crop cultivated on this acreage. Table 2 shows that the acreage of pesticide-intensive cultivations such as fruits, vegetables, ornamental crops and potatoes has increased significantly between 1979 and 2002. Horticultural crops are cultivated on a rather small acreage (ca. 8%) and thus represent high amounts (ca. 31%) used per unit area. An increase of pesticide-intensive crops from 1979 until the beginning of the 1990s has resulted in an increase of overall pesticide use. From 1992 a reduction of the total usage can be observed, although the crop acreages of intensive cultivation still tend to increase. This implicates that substitutions of PPPs may have an

effect on the reduction of pesticide use from the 1990s onwards.

For a sustainable agriculture the dependency on pesticide use plays an important key factor in a further decrease in their use. Ekkes et al. (2001) selected several indicators which can describe the dependency on pesticide use on farm level:

- acreage with tolerant or resistant strains,
- acreage with non-chemical (i.e. biological or mechanical control) of the main pest or disease,
- acreage treated with biological products,
- percentage of the acreage under guidance systems,
- number of farms under environmental protocol or with an acknowledged environmental policy plan,
- number of participants within a quality system.

In the Belgian agricultural sector, the striving for a sustainable agriculture is a main focus in ongoing research. Integration of reduction strategies mentioned above has become an important instrument in Belgian agriculture, but the extent in which these strategies have been adopted is not yet clear and needs further investigation. However, it can be seen that the use of warning systems (fruit, potatoes), integrated pest control (fruits, vegetables), technical measures such as mechanical weeding (maize, cereals), continuous education of farmers has taken its place in Belgian agriculture. For example acreage of fruit cultivation in Flanders with integrated pest control increased from 2339 ha in 1996 to 10 572 ha in 2002, which represents 77% of the total acreage for fruit production. The acreage of organic farming increased from 640 ha in 1994 to 3879 ha in 2002. The goal of 10% organic farming in 2010 remains however far away.

In addition, pesticide reduction measures and strategies play an important role for a sustainable agricultural sector not only because of a reduction of pesticide use but mainly because of a reduced dependence on crop protection products. However, it is important that no negative economic consequences for farmers are involved (either higher costs or lower yields). In the near future a combination of these pesticide reduction strategies should lead to a further structured reduction, in which good communication and creating awareness is a major task for the proper authorities and institutes in order to reduce environmental pressure.

In 2001, the Flemish authorities adopted a decree on the reduction of pesticide use by public services in Flanders. It states that all public services in Flanders should have set up a reduction programme towards pesticide use in June 2003. Non-submission of such a reduction plan to the proper authorities automatically implied a total prohibition of pesticide use from the beginning of 2004. Approval of the reduction plan allows further use but under strict conditions. Furthermore, it is a goal to have a complete ban of pesticide use by public services in 2015, the year in which the European Commission in light of the Water Framework Directive 2000/60/EC obliges its member states to reduce the occurrence of pesticides in water to a level necessary for a healthy environment. From this decree a further reduction of pesticide use is expected in the near future.

### 3.2. Evolution of the $\sum$seq risk indicator

Fig. 5 describes the evolution of the $\sum$Seq for both agricultural and non-agricultural use. Compared to 1990 a decrease of 47% was established in 2002. Horticulture, arable farming and non-agricultural use account on average for 48%, 29% and 23%, respectively, in the total $\sum$Seq. Only small fluctuations are observed within this period. As often is the case for single-impact risk indicators, a limited number of pesticides are responsible for the major part of the total

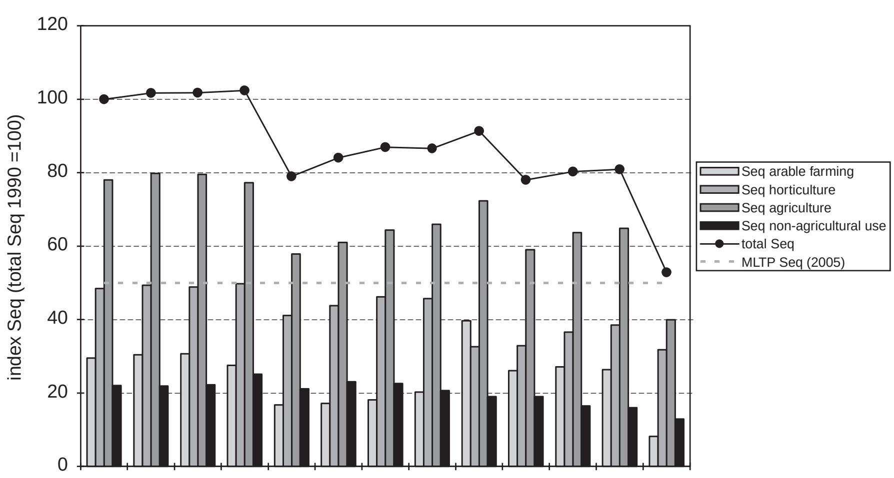


Fig. 5. Evolution of the $\sum$Seq in Flanders between 1990 and 2002 (index 1990 = 100).

environmental pressure. In 1990, lindane, diuron, paraquat, flufenoxuron, fenoxycarb, parathion and chlorpyriphos accounted for 83% in the total $\sum$Seq. The evolution of the $\sum$Seq is mainly controlled by a variation in sales data of lindane, diuron and paraquat. Use of lindane and parathion was prohibited in 2001 and 2002, respectively, in Belgium, whereas the use of paraquat has stagnated since 1999 and is lower in comparison to 1990. From 01/01/2003 the use of some 40 active ingredients (from a total of 375 authorized active ingredients) are prohibited or restricted by the Belgian authorities. Whether the goal of a 50% reduction of the $\sum$Seq in 2005 will be completely accomplished remains uncertain and mainly depends on the use of other pesticides having a high score in the indicator.

As was mentioned earlier, a limited number of pesticides account for the major part of the total $\sum$Seq. Within the DPSI-R analysis frame response from the authorities should have the most significant effect on reducing environmental risk when taking action at the pressure level. Prohibition or restricted use of hazardous crop protection products is probably the most vivid example of such responses. Further restrictions are expected within the framework of Council Directive 91/414/EEC.

Additional restrictions of such hazardous products imposed by the authorities could initiate a further decrease of the total $\sum$Seq. However, it should be carefully considered and not be solely based on such indicators. For most single-impact risk indicators, including the $\sum$Seq, one should keep in mind the limitations of such tools. The results of such indicators should always be subjected to expert-judgement.

Important factors determining possible environmental contamination are formulation type or application method and possible spray drift, especially when fields are located in the near vicinity of surface waters. When pesticides are applied as granules or seed treatment for instance, less risk for the aquatic environment can be assumed than when applied as wettable powder. With regard to possible spray drift the introduction of a spray buffer zone can reduce direct contamination of surface water to a great extent. De Lijster (1998) investigated the effect of introducing a buffer zone in several crop types. The study showed that a 3m-buffer zone could reduce the direct load of pesticides into surface waters with a minimum of 95%. In general, Good Agricultural Practice plays an important role in reducing the potential risk for the direct contamination of surface waters.

These findings are not included in most single-impact risk indicators, but are important aspects to consider when setting out new environmental policies regarding restrictions of crop protection products. It should be noted that some other risk indicators (REXTOX, EYP and SYPEP) take into account some of these limitations, i.e. application method, spray buffer zones and percentage run off and can provide additional information and better measures for the actual situation. However, these indicators require detailed information such as field slope, amount of precipitation, soil type, width of buffer zones, application method, etc. Intensive research is needed to provide such information and although feasible at farm scale or local scale, its applicability at regional scale would be narrow. Introduction of default-values for use of these indicators at regional scale can be a solution, but will reduce the effect of the parameters involved. Furthermore, it was shown that simple indicators produce risk trends very similar to risk trends provided by more complex and data-intensive indicators (OECD, 2002).

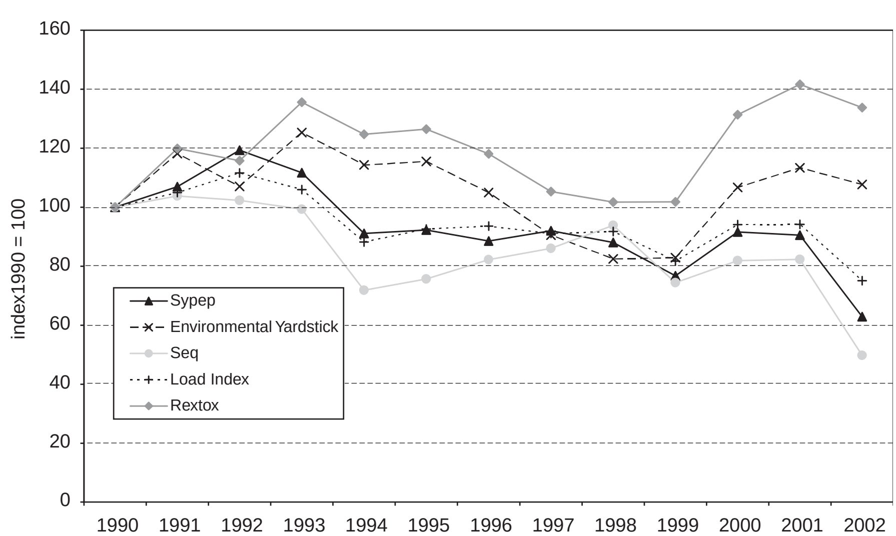


Fig. 6. Comparison of the Seq index with other indices.

Table 3
The top 20 pesticides having the highest score in the selected pesticide risk indices

| EYP | | REXTOX | | SyPEP | | Load Index | | $\sum$Seq | |
|---|---|---|---|---|---|---|---|---|---|
| Pesticide | Contribution (%) | Pesticide | Contribution (%) | Pesticide | Contribution (%) | Pesticide | Contribution (%) | Pesticide | Contribution (%) |
| Fenoxycarb | 59.0 | Fenoxycarb | 55.8 | Fenoxycarb | 22.5 | Fenoxycarb | 20.0 | Lindane | 44.6 |
| Phosalone | 5.5 | Phosalone | 5.2 | Lenacil | 16.7 | Parathion | 12.0 | Paraquat | 8.1 |
| Dodine | 5.1 | Dodine | 4.9 | Parathion | 9.6 | Lindane | 9.4 | Parathion | 7.7 |
| Endosufan | 5.1 | Endosufan | 4.5 | Lindane | 4.6 | Diuron | 4.5 | Fenoxycarb | 5.2 |
| Diuron | 4.3 | Parathion | 3.5 | Diuron | 4.3 | Endosulfan | 3.8 | Aclonifen | 4.6 |
| Parathion | 2.2 | Diuron | 3.4 | Dodine | 3.7 | Monolinuron | 3.6 | Diuron | 4.2 |
| Deltamethrin | 1.8 | Lindane | 2.2 | Chlorpyriphos | 3.5 | Aclonifen | 3.2 | Lenacil | 3.1 |
| Paraquat | 1.8 | Deltamethrin | 1.9 | Flufenoxuron | 2.9 | Diazinon | 2.8 | Chlorpyriphos | 2.8 |
| Tolylfluanid | 1.7 | Tolylfluanid | 1.6 | Dichlorvos | 2.5 | Deltamethrin | 2.2 | Endosulfan | 2.4 |
| Chlortoluron | 1.2 | Chlortoluron | 1.4 | Permethrin | 2.3 | Bifenox | 2.1 | Monolinuron | 2.4 |
| Diflubenzuron | 1.2 | Paraquat | 1.4 | Endosulfan | 2.3 | Dinoterb | 1.9 | Methabenzthiazuron | 1.5 |
| Lindane | 1.0 | Diflubenzuron | 1.1 | Deltamethrin | 2.2 | Phosalone | 1.9 | Diflufenican | 1.5 |
| Diazinon | 0.8 | Monolinuron | 0.9 | Aclonifen | 2.2 | Pirimiphos-Me | 1.9 | Chlortoluron | 1.2 |
| Bifenthrin | 0.7 | Diazinon | 0.8 | Mancozeb | 2.2 | Chlorpyriphos | 1.8 | Bifenthrin | 1.1 |
| Pyridaben | 0.7 | Aclonifen | 0.7 | Diazinon | 1.8 | Dodine | 1.7 | Tefluthrin | 0.8 |
| Permethrin | 0.7 | Bifenthrin | 0.7 | Paraquat | 1.4 | Paraquat | 1.7 | Diazinon | 0.8 |
| Azocyclotin | 0.5 | Pyridaben | 0.7 | Tolylfluanid | 1.1 | Fentin-acetate | 1.5 | Pirimiphos-Me | 0.7 |
| Foxim | 0.5 | Chlorpyriphos | 0.6 | Heptenophos | 1.0 | Foxim | 1.5 | Deltamethrin | 0.6 |
| Chlorpyriphos | 0.4 | Lenacil | 0.6 | Chlortoluron | 0.9 | Permethrin | 1.4 | Fentin-acetate | 0.6 |
| Pyrifenox | 0.4 | Dinoterb | 0.5 | Tefluthrin | 0.9 | Chlortoluron | 1.4 | Dodine | 0.5 |

In agreement with OECD (2002), a high variability and sensitivity was observed for the $\sum$Seq to the quality of the input data, especially regarding the eco-toxicity data. The evolution of such indicators can change significantly dependent on the choice of input data. As more high-quality information becomes available in view of directive 91/414/EEC these problems should be eliminated in the future.

### 3.3. Comparison with other pesticide risk indicators

Fig. 6 shows the comparison of the $\sum$Seq index with other pesticide indices. In agreement with the $\sum$Seq index, the evolution of these indices is controlled by just a few pesticides. For each risk index the pesticides with the highest ranking (top 20) and their contribution are shown in Table 3. Although the sequence of each individual pesticide within these ranking systems can change according to the index, it can be seen that often the same pesticides have a high score. Eight pesticides are found in all five indices: deltamethrin, diazinon, diuron, endosulfan, fenoxycarb, lindane, paraquat and parathion. It can be seen that the evolution of the $\sum$Seq is quite similar to the evolution of the Load Index. The $\sum$Seq index favours persistent compounds such as lindane and paraquat. Furthermore, it can be seen from Fig. 6 that the evolution of the EYP index and the REXTOX index is very similar. Unlike the $\sum$Seq and the LI these two risk indices estimate PECs in surface waters, in which spraydrift is the major emission source. Whereas pesticide losses due to spraydrift are expected to be higher in orchard spraying (ca. 6.4% according to Ganzelmeier, 1997), pesticides used in these cultivations should be favoured within these ranking systems. Both EYP and REXTOX are controlled by pesticides mainly used in fruit orchards in Flanders: fenoxycarb (100% use in fruit), phosalone (100%), dodine (100%) and endosulfan (37%). The evolution of both indices is therefore very similar (Fig. 6).

The SyPEP index accounts for additional emission sources. Whereas in the SyPEP index spraydrift is not considered to be the most important emission source, i.e. losses due to direct contamination, run-off and draining for highly mobile pesticides are thought to be higher, other pesticides are responsible for the evolution of risk index. However, it can be concluded that for all five risk indices in general the same pesticides have a high score when ranked in order of importance. As mentioned earlier this does not necessarily mean that these pesticides will pose risk to the environment, but that at least careful handling and appropriate application within the Good Agricultural Practices must be considered.

Depending on which pesticides have the highest score, the evolution of the index will differ. This explains the similarities and differences as described earlier when comparing all indices.

## 4. Conclusion

The pesticide risk indicator $\sum$Seq requires limited data input and provides an easy tool for environmental policy planning. However, such indicators have their limitations, especially when applied in a legislative framework. Careful consideration is necessary within such a framework and a more case by case approach is advisable. Furthermore, the quality of the input-data has shown to be of great importance. The use of multi-impact risk indicators such as the POCER-risk indicator have the advantage that risk can be assessed for multiple components such as human exposure and other environmental compartments. Dependent on the quality of the underlying models and calculations, the output of more complex indicators should be closer to the real situation. However, such indicators are often too complex and data-intensive which reduces their applicability on a regional scale. It is therefore not surprising that easy tools such as $\sum$Seq, FA and annual consumption are used in environmental policy planning. Therefore, it can be concluded that the choice of the $\sum$Seq index as a policy tool in Flanders can be justified when comparing with other risk indices. The results of the $\sum$Seq index are very similar to other risk indices but however giving the advantage that less parameters should be taken into account. These simple indicators can provide a good first tier approach, whilst keeping in mind the limitations of these tools.

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